[AMERICAN JOURNAL OF SCIENCE, VOL. 267, OCTOBER, 1969, P. 983-987]

THE OCCURRENCE OF CHARNOCKITE IN THE ADIRONDACKS: A NOTE ON THE ORIGIN AND DEFINITION OF CHARNOCKITE

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ABSTRACT. Charnockites in the Adirondacks are predominantly metamorphic rocks occurring in two ways: as layers of metavolcanics or metasediments in a folded stratigraphic sequence of supracrustal rocks and as more homogeneous masses in the basement below the supracrustal sequence. In the latter case it may have been derived from plutonic granite or from charnockite forming part of the magmatic anorthosite-charnockite suite of rocks. Outside the Adirondacks unmetamorphosed magmatic charnockite is known to occur associated with anorthosite.

Magmatic charnockite is represented in the Adirondacks by the metatect of crocyditic and dictyonitic migmatites, which occur locally in metamorphic charnockite. Hence, charnockite is formed (1) by metamorphism from preexisting rocks of granitic bulk composition under granulite-facies conditions, and (2) by crystallization from anatectic melt or differentiated magma under conditions of the granulite mineral facies.

Conforming to general usage of the term today, charnockite is defined as a rock that occurs most commonly as a metamorphic rock, but also as a magmatic rock, and that has the bulk composition of granite, contains orthopyroxene and perthitic feldspar, and has a characteristic dark, commonly gray-green color. In rocks with very high Fe/Mg ratio fayalite and quartz substitute for orthopyroxene.

Is charnockite a magmatic or a metamorphic rock, and, in either case, what controls its formation? These two questions sum up the charnockite problem. Cooray's (1969) view, that charnockite is almost exclusively a metamorphic rock of the granulite facies, may well reflect the consensus of geologists working in high-grade metamorphic terranes in which the rock occurs. It reflects also the view of this writer concerning the nature of charnockite in the Adirondack highlands.

Charnockite is a common rock type in the granulite facies of the Adirondacks (for example, Buddington and Leonard, 1962) and the adjacent Precambrian region in Canada (for example, Wynne-Edwards and others, 1966), though it has been referred to more commonly as quartz syenite, syenite gneiss, or charnockitic gneiss (see also, Broughton and others, 1962). Almost all the charnockite occurrences in the Adirondacks have a metamorphic habit. The rock is typically foliated, has a gray-green color, and contains orthopyroxene. The exception is the patchy metatect of crocyditic and dictyonitic migmatites, which have locally developed in the foliated charnockite by anatexis (de Waard and Walton, 1967). The charnockite of the metatect is also gray-green in color and bears orthopyroxene, but it has a massive, igneous texture. The contact between the magmatic and metamorphic charnockite is gradational.

Charnockitic rock units were mapped in detail in the Little Moose Mountain syncline (de Waard, 1962, 1964). The charnockite occurs here in sheets or layers which are interbedded and folded together with layers of marble, amphibolite, quartzite, and pelitic gneiss in a completely conformable sequence. It seems unlikely that the sheets were formed by injection of charnockite magma without causing intrusive phenomena and without disturbing the thin marble and gneiss layers between them. Instead it was proposed that the charnockite layers represent metamorphosed supracrustal deposits, sedimentary, tuffaceous, or volcanic. Acid volcanic flows seem to be indicated particularly because of the relatively low water content of the rock.

Charnockites of supracrustal origin, rocks now metamorphic but derived from sediments or volcanics, thus form part of the stratigraphic sequence in the Adirondacks. The sequence rests upon a basement of pre-Grenville origin in which, among other rock units, massifs of charnockite are recognized (Walton and de Waard, 1963; de Waard and Walton, 1967). Here also the charnockite is now a foliated metamorphic rock derived from a preexisting rock of granitic bulk composition and with a relatively low water content, such as granite or gneiss. The basement charnockites are more homogeneous and have less of a layered habit than the charnockites belonging to the supracrustal sequence. In hand specimen or thin section, however, no characteristic difference can be detected.

At least part of the basement charnockites belong to a rock suite in which anorthosite is the other end member of the series (de Waard and Romey, 1963, 1969a, b). Here, also these charnockites are now metamorphic rocks, but it is clear that before metamorphism they were formed as part of a magmatic series. In this series anorthosite developed first and was followed by rocks with increasing K-feldspar and quartz content. The series was concluded with crystallization, either of granite or of charnockite.

The formation of charnockite from magma, as a member of the anorthosite-charnockite suite, is best studied outside the Grenville Province where these rocks have not been affected by metamorphism and tectonism during the Grenville orogeny. One such area is the Nain region in Labrador where gray-green, hypersthene-bearing, magmatic rocks of granitic and granodioritic bulk composition occur in an igneous complex ranging in rock type from anorthosite to granite (Wheeler, 1955, 1960, 1969; de Waard, 1969a).

Hence, charnockite, though most commonly occurring as a metamorphic rock in high-grade metamorphic terranes, may also occur as a magmatic rock, formed either by anatexis in high-grade metamorphic areas or by differentiation or some other process in anorthosite complexes. The diverse ways of origin are shown in table 1. It may seem unusual to employ the same term for a metamorphic rock and a magmatic rock. However, the two are much more alike than unlike. Both have the same characteristic color, diagnostic minerals, mineral assemblage, and bulk composition; they differ only in texture. The reason for this convergence is that they are formed under the same environmental conditions from material of the same bulk composition, solid or liquid.

TABLE 1

Convergence in origin of charnockite

Source materials	*P-T conditions:* the granulite mineral facies, that is: medium-high T; medium-high P_{load}; low-medium P_{H_2O}	*Product*
rocks of granitic bulk composition {sedimentary, volcanic, plutonic, metamorphic}	metamorphism	CHARNOCKITE
↓ anatectic melt; differentiation and other possible sources of magma of granitic bulk composition	crystallization	CHARNOCKITE

Diagnostic for charnockite is the presence of orthopyroxene in the mineral assemblage. As orthopyroxene is also the diagnostic mineral of the granulite facies in regional metamorphism, it follows that charnockite is a product of granulite-facies environment. Why in a granulite-facies terrane like the Adirondacks granitic gneisses and charnockite may occur side by side, having the same bulk composition and formed under the same P_{load}-T conditions, yet having developed different mineral assemblages, has been explained by differences in the water content of the parent rock (de Waard, 1966, 1967). Charnockite is considered to have formed from initially relatively dry rocks such as volcanic flows in the supracrustal sequence, and from granite, charnockite, and the previously dehydrated gneisses in the basement complex. Unless temperatures were very high, a relatively low water-vapor pressure is a requirement for the formation of orthopyroxene, which is a product of dehydration reactions (de Waard, 1969b).

Conditions of the granulite facies may be described as having a P_{load}/T ratio of regional metamorphism and P_{H_2O} such that orthopyroxene is a stable mineral. In general terms such conditions may range from medium T, medium P_{load}, and low P_{H_2O}, to high T, high P_{load}, and medium P_{H_2O}. Similarly, magmatic charnockite crystallized under conditions of the granulite mineral facies, that is, from a relatively dry magma under P_{H_2O}-T conditions at which orthopyroxene is stable.

The question: what is a charnockite and how is the term best defined, cannot be ignored completely. This writer, when studying the field occurrence of charnockite in the type area near Pallavaram in India, was impressed by the metamorphic nature of the rock, which is most strikingly displayed on the weathered surface, and by the absence of intrusive and magmatic features. The rock of the type area, therefore, does not seem to restrict the definition to a magmatic rock as Holland (1900) attempted to prove. Also Holland's subdivision into acid, intermediate, and basic charnockites as members of his Charnockite series, though still used by some, has now become obsolete. As mostly used today the term represents Holland's charnockite proper, or acid charnockite, which is a rock with the bulk composition of granite. The presence of orthopyroxene is diagnostic, although hornblende, or biotite, or both may be additional mineral phases. The feldspar is commonly perthitic, and the rock has a characteristic dark, gray-green, brownish, blackish, or waxy appearance due to the color of the feldspar and quartz. The quartz is sometimes described as having a blue color.

One addition to the definition of charnockite should be made in order to update the term. In charnockite with a very high Fe/Mg ratio orthopyroxene is not found, but fayalite and quartz have developed instead. Fayalite-bearing charnockite of magmatic origin is known from the Nain region (Wheeler, 1955, 1965), and metamorphic fayalite-bearing charnockite, described as fayalite-ferrohedenbergite granite (Buddington and Leonard, 1962) is known from the Adirondacks (de Waard, 1969a).

There are appropriate, mostly Norwegian, names for rocks, magmatic as well as metamorphic, which are similarly dark, greenish, and waxy-looking, bearing orthopyroxene and perthitic feldspar, and which are therefore related to charnockite in the environment of formation, but which differ from charnockite in bulk composition. These are mangerite, farsundite, jotunite, enderbite, norite, et cetera, representing rocks of Holland's intermediate and basic divisions (de Waard, 1969a).

In conclusion, the definition and development of charnockite are summarized as follows. Charnockite is defined as a rock that occurs most commonly as a metamorphic rock, but also as a magmatic rock, and that has the bulk composition of granite, contains orthopyroxene (or fayalite and quartz) and perthitic feldspar, and has a characteristic dark, commonly gray-green color. Its formation is controlled by composition and environment. Charnockite is produced in the granulite mineral facies, that is, under P_{load}-T conditions of regional metamorphism and P_{H_2O} such that orthopyroxene (or fayalite plus quartz) is formed, and from material of granitic bulk composition, either solid or liquid.

ACKNOWLEDGMENTS

Field research on the occurrences of charnockite and anorthosite in the Adirondacks, Labrador, and southwest Norway has been supported by National Science Foundation Research Grants. A Guggenheim Fellowship made possible field studies of charnockite in Europe, India, Ceylon, and Australia.

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